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# THE BAKING QUALITIES OF FLOUR

## As Influenced by Certain Chemical Substances, Milling By-products, and Germination of the Wheat.

(ABSTRACT).

By J. T. WILLARD and C. O. SWANSON.

THE milling tests of wheat and baking tests of flour conducted by the department of chemistry began in 1905, when an experimental reduction mill was purchased. During that year Mr. W. E. Mathewson, in a research conducted as a part of his work for the master's degree, made very careful analyses of several flours, including determinations of the percentages of each of the distinct proteids present, and compared their chemical composition with their baking qualities as shown by baking tests made for us in the department of domestic science. At that time the statement was frequently made, and perhaps is, even to-day, that the ratio of the gliadin to the glutenin of the flour determines its baking qualities. Mr. Mathewson's results threw grave doubt on this supposition, and all subsequent investigations in the department have confirmed the view suggested at that time, namely, that the chemical factors entering into the baking quality of flour are more complex than that. Flours may be very good in their content of gliadin and in the gliadin-glutenin ratio, and yet be inferior in baking qualities to others with supposedly less favorable composition. Of two flours essentially the same in respect to these data, one may be very good and the other very poor.

As a result of such observations the department has been conducting numerous experiments designed to throw light on the subject of baking quality in flour. Many of these do not come within the scope of the present paper, which is concerned with the effects of the addition of certain substances to the flour. These tests were suggested by the thought that, inasmuch as considerable differences in respect to the gliadin and the gliadin-glutenin ratio did not in themselves appear to influence the results much, it might easily be true that the difference in baking qualities exhibited might be caused by substances present in very small amounts. It will be recalled that capacity to produce a good loaf depends on the quality of the gluten that a given flour can yield, other conditions being favorable. Gluten does not exist as such in the flour, but is produced, in a manner not altogether understood, from constituents existing in the flour, chiefly the gliadin and the glutenin, when the flour is stirred with water.

Gliadin is a gluey, adhesive substance which binds the glutenin and other constituents of the flour together in the dough and produces the well-known condition so essential to the production of good bread, in which the carbon dioxide produced by yeast is held in small bubbles that give the loaf its lightness. If the gluten is too weak the partitions between the globules are broken, and globules coalesce, with the production of coarse-grained bread. A weak gluten will yield under the weight of the loaf, and, instead of rising in a well-rounded form, will flatten out and run over the edge of the pan, if possible. The production of a good loaf depends on the physical properties of the gluten. It is well known that small percentages of substances may cause very great differences in the physical properties of mixtures. It is, therefore, quite reasonable to expect that the physical properties of gluten may be profoundly affected by small quantities of associated substances. This would be a purely physical phenomenon. It is, however, also possible that small quantities of substances may influence the character of the loaf in an entirely different manner, by favoring or inhibiting, as the case may be, the growth of the yeast.

It is well known that graham flour lacks the power to yield as round and light a loaf as does white flour produced from the same wheat. This fact suggested experiments to ascertain the effect of substances in the bran and shorts the action of which is excluded from white flour. These effects were tested in different ways, which will be detailed later, using bran, extracted bran, extract from bran, extract from wheat scourings, etc.

Recent research has shown that the protein substances consist in large part of nuclei derived from a considerable number of amino acids. It is highly probable that, in the growth of the yeast in the flour, hydrolysis of the proteins takes place with the liberation of some of these amino acids, and it is possible that they play an important part in the development of the yeast, or affect the physical properties of the gluten. A part of our study in this connection then, has been to ascertain what effect, if any, the addition of small amounts of amino acids has on the character of the loaf produced. As but few of the amino acids represented in proteins are to be purchased in the market, our experiments in this line are not completed as yet. It is planned to import as complete a list of these substances as can be obtained for continuation of this investigation.

A considerable number of observations are made in connection with each baking test, and a detailed study of any set of these would involve considerable time and the inspection of many figures —a proceeding that would be wearisome to all not especially interested in this line of work. In most cases, therefore, only the figures for loaf volume are presented.

In addition to the experiments using amino acids, others have been made with salts such as might be present in the flour or that are related to them.

The accompanying table exhibits the results obtained with bran, etc. If bran were merely a diluent, and without active effect on the gluten, we should expect that the quality of the loaf would be affected by incorporating a considerable percentage of it with the flour. To offset this effect of dilution a loaf was made in which an equal weight of starch was used instead of bran, starch being presumed to be without specific influence, or, at least, without much influence except as a diluent. In all of our baking tests a check loaf is baked from the untreated standard flour, and with this, as a rule, all others are to be compared. The difficulty of conducting exactly comparable baking tests is such that, without such a test loaf produced by a parallel treatment in each baking, it would be impossible to draw any conclusions. Of the results obtained with the bran, in addition to loaf volume, there is presented the scoring as to texture, and total time in minutes required for the rising.

The bran used in these tests was free from scourings or screenings of any kind. In preparing the extracts, 500 grams were treated with 2000 cc. of water. The bran was allowed to soak over night, and then placed on linen and the extract squeezed out. The residue was treated several times with additional portions of water in preparing the washed bran. In extracting hot, the bran was boiled about ten minutes with water, then washed several times on linen with hot water, the water being squeezed out.

The table shows that the unextracted bran had a notable deteriorating effect on the loaf, in respect to both volume and texture, as compared with the check loaf or with the loaf to which an equal weight of starch was added. The extracted bran was less marked in its effect on loaf texture, and the loaf volume exceeded that of the loaf in which starch was used. The loaf in which the extract from 40 grams of bran was used was the best of all. The fact that extracted bran and bran extract each produces better results than when the two coexist in the enextracted bran is something that would not have been expected, but which was confirmed by the repetition of the test.

EFFECT OF BRAN, BRAN EXTRACT, AND STARCH.

| | Time for total rise, minutes. | | Loaf volume. | | Loaf texture. 100=Perfection. | |
|---|---|---|---|---|---|---|
| | *I* | *II* | *I* | *II* | *I* | *II* |
| Check | 173 | 162 | 1430 | 1410 | 95 | 95 |
| Starch, 40g | 168 | 159 | 1290 | 1290 | 95 | 95 |
| Bran, 40g | 154 | 143 | 1260 | 1250 | 91 | 91 |
| Bran, extracted by cold water, 40g | 148 | 137 | 1380 | 1370 | 92 | 92 |
| Bran, extracted by hot water, 40g | 142 | 137 | 1300 | 1310 | 92 | 92 |
| Extract from 40g. bran, cold water | 136 | 127 | 1520 | 1540 | 96 | 96 |

LOAF VOLUME AS AFFECTED BY DIFFERENT SUBSTANCES.

| SUBSTANCE ADDED. | Minimum amount. | Times minimum amount— | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 4 | 8 | 16 |
| Bran extract, cold extraction | 2.5g.* | 1480 | 1490 | 1410 | 1510 | 1520 | 1520 |
| Bran extract, cold extraction, filtered | 2.5g.* | 1470 | 1500 | 1520 | 1550 | 1550 | 1550 |
| Bran extract, hot extraction | 2.5g.* | 1400 | 1420 | 1440 | 1520 | 1550 | 1560 |
| Wheat-scourings, extract I | 2.5g.* | 1450 | 1480 | 1500 | 1520 | 1540 | 1490 |
| Wheat-scourings, extract II | 2.5g.* | 1360 | 1460 | 1280 | 1360 | 1260 | 1190 |
| Peptones | 0.4g. | 1380 | 1390 | 1370 | 1280 | 1300 | 1320 |
| Glycocoll, $CH_2(NH_2)$, $COOH$ | 0.1g. | 1380 | 1330 | 1270 | 1240 | 1180 | 1180 |
| Leucin, $(CH_3)_2$, $CH$, $CH_2(NH_2)$, $CH$, $COOH$ | 0.025g. | 1380 | 1340 | 1280 | 1270 | 1360 | 1330 |
| Aspartic acid, $COOH$, $CH_2$, $CH(NH_2)$, $COOH$ | 0.1g. | 1460 | 1470 | 1460 | 1420 | 1500 | 1530 |
| Asparagin, $CO\ NH_2$, $CH_2$, $CH(NH_2)$, $COOH+H_2O$ | 0.1g. | 1440 | 1410 | 1380 | 1380 | 1300 | 1370 |
| Ammonium acetate, $CH_3$, $COONH_4$ | 0.1g. | 1440 | 1490 | 1490 | 1500 | 1520 | 1500 |
| Ammonium tartrate, $NH_4OOC$, $CHOH$, $CHOH$, $COONH_4$ | 0.1g. | 1460 | 1470 | 1450 | 1520 | 1550 | 1400 |
| Ammonium chloride, $NH_4Cl$ | 0.025g. | 1300 | 1420 | 1260 | 1520 | 1600 | 1610 |
| Ammonium phosphate, $(NH_4)_2HPO_4$ | 0.1g. | 1470 | 1470 | 1470 | 1470 | 1440 | 1430 |
| Sodium phosphate, $Na_2HPO_4$ | 0.4g. | 1430 | 1450 | 1460 | 1400 | 1410 | 1420 |
| Sodium bicarbonate, $NaHCO_3$ | 0.1g. | 1330 | 1370 | 1350 | 1210 | 1170 | 1170 |
| Sodium formate, $H$, $COONa$ | 0.1g. | 1550 | 1530 | 1500 | 1470 | 1550 | 1500 |
| Potassium nitrate, $KNO_3$ | 0.1g. | 1500 | 1480 | 1440 | 1500 | 1520 | 1520 |

* These figures show the weights of material extracted.

The second table gives data concerning the effect of various substances on loaf volume. Bran extracts were used in quantities obtained from weights of bran in geometrical ratio. The larger amounts produced greater effects in the same direction. In the case of the loaf with which extract prepared with hot water was used, the largest amount caused a poorer texture of loaf, and with the other two cases the deteriorating effect of the increased quantities was manifested when the extract was used in still less amounts.

The effects of extracts derived from wheat scourings are, on the whole, undesirable, though in respect to loaf volume this does not appear in one of the trials. The doughs produced were sticky and undesirable, and the effects were more pronounced with the larger quantities of extract.

When peptones were added to the flour in amounts of from 0.1 gram to 1.0 gram but little effect was observed, but with larger quantities they were deleterious to the texture and loaf volume. Their most marked effect was in producing a notable stickiness in the dough. Peptones were tried because of their relation to proteids and amino acids, being intermediate in chemical complexity and structure.

Glycocoll was very pronounced in its effects, producing a dough that was sticky, runny and stringy. It would stretch out like taffy, but lacked in elasticity. It resembled the dough produced from flour made from badly germinated wheat. The loaf volume was distinctly reduced and the texture impaired.

The effects of leucin were similar to those of glycocoll, but not so pronounced. It caused, however, the development of a very disagreeable odor.

Aspartic acid did not have any very great effect, but such as was produced was beneficial rather than otherwise.

Asparagin, however—the amide of aspartic acid—was injurious in its effects. While it caused a shortening of the time of rising, probably by a stimulation of the growth of the yeast, it weakened the gluten, thus decreasing the oven expansion and loaf volume. Similar effects are observed with flour from germinated wheat, and asparagin is well known as one of the products of the proteid metabolism accompanying germination.

Of the ammonium salts tried, ammonium chloride had so marked an effect that the quantities used were cut down to a minimum of 0.025 gram. This amount and up to sixteen times as much, at least, had a most pronounced beneficial effect on the texture and loaf volume. The salt apparently assists the growth of the yeast, as the period of rising is shortened. Ammonium acetate has a similar but much less marked effect. In the larger amounts, however, it impaired the quality of the loaf in respect to texture. Ammonium tartrate had a very slight effect, and the same is true of ammonium phosphate. In the latter case the results upon the six loaves might almost be taken as an example of concordance of parallel uniform tests.

Sodium bicarbonate was distinctly detrimental in its effects, increasing the time of rising and diminishing the volume of the loaf. Sodium phosphate, sodium formate and potassium nitrate do not call for any special comment at this time.

On the whole, it is evident that chemical substances in many cases have distinct, and in some cases very pronounced, effects upon the baking qualities of flour, and it is believed that a field has been opened that will repay further working. It is highly probable that the differences in the baking quality of flours are due to small differences in their content of these and similar substances as much as to their differences in composition in respect to the chief constituents.

BAKING TEST ON FLOUR FROM GERMINATED WHEAT.

| NUMBER. | Loss in germination and drying.... | Loss in scouring......... | Per cent total loss..... | Per cent of moisture.... | Per cent of absorption... | Time of rising. | Weight of baked loaf, g. | Volume of loaf, cu. in.. | Per cent gliadin is of protein..... | Amino-nitrogen × 6.25.. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1........................... | 83 | 75 | 5.5 | 11.07 | 59.2 | 1:52 | 515 | 83 | 52.4 | 0.136 |
| 2........................... | 43 | 86 | 4.3 | 12 00 | 52.5 | 2:13 | 509 | 88 | 52.7 | 0.144 |
| 3........................... | 100 | 80 | 6.3 | 11.37 | 50.8 | 2:03 | 504 | 93 | 55.8 | 0.184 |
| 4........................... | 149 | 200 | 11 6 | 11.67 | 49.17 | 2:17 | 498 | 84 | 55.8 | 0.247 |
| 5........................... | 250 | 452 | 23.4 | 10.65 | 47.5 | 2:55 | 492 | 84 | 56.5 | 0.351 |
| 6........................... | 54 | 52 | 3.5 | 11.55 | 54.2 | 1:58 | 515 | 97 | 50.7 | 0.192 |
| 7........................... | 160 | 63 | 7.4 | 8.50 | 56.67 | 2:25 | 524 | 69 | 43.4 | 0.512 |
| 8........................... | 0 | 23 | 1.6 | 11.71 | 56.67 | 1:25 | 524 | 85 | 48.4 | 0.128 |

Considerable study has been made of the effects of germination of wheat upon the baking qualities of flour produced from it, and the effect of such flour when mixed with flour from sound wheat. As germination produces amino compounds, it was to be expected that somewhat similar results would be obtained with flour made from germinated wheat as with flour to which amino compounds had been added. This was found to be the case. The accompanying table shows part of the results obtained in this connection. No. 8 is the check, and shows the results obtained with sound wheat. Nos. 1, 6 and 7 were germinated one day; No. 2, two days; No. 3, three days; No. 4, four days, and No. 5, five days. In the germination the wheat was placed between layers of cheesecloth on a bed of wet sand, the whole being sprinkled four times a day. All of the samples but No. 6 were covered by muslin bags which had been soaked in a solution of formaldehyde. This was for the purpose of preventing mold. All of the germinated samples excepting No. 7 were spread out on a cloth on the floor to dry. No. 7 was dried for two days in a steam oven instead of on the floor. The weather was warm, and two days' exposure to conditions for germination gave results that were readily perceptible to the eye. The table shows the more interesting data obtained. Up to the third but little effect on the baking quality was observed. After that the loss on germination became very noticeable and the quality of the bread deteriorated. While the loaf volume was increased for the first three days, after that it dropped back, and accompanying this there was a noticeable deterioration in the texture of the crumb. In the case of No. 7, which was dried by steam heat, a very serious injury to the flour was observed. This is shown in part by the small loaf volume. The texture of the loaf was very poor, and the alcohol-soluble protein considerably diminished.

In a second series of experiments baking tests were made with standard flour, and with flour made from badly germinated wheat, and with various mixtures of the two. The deleterious influence of the flour from the germinated wheat was strongly manifested even when only one-thirtieth of the mixture was flour from such wheat. With larger amounts the product showed that the mixtures were wholly unfit for bread making. The evil effects of mixing wheat damaged by germination with sound wheat was brought out for the first time by these experiments. Such wheat may be manipulated so that when mixed in small quantities with sound wheat it can scarcely be detected.